Autonomous µSystem for TRAnsmission WireLess

The ASTRAL network

Authors :
H. Rouault (CEA-Liten), L. Daniel, P. Jost, P. Klein, F. Favre-Reguillon (CEA-Leti),
P. Pelissou (EADS-Astrium), M.C. Vassal (3DPlus)

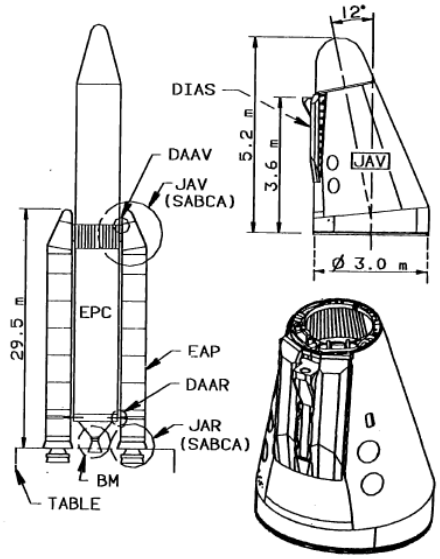
Presentation Outline

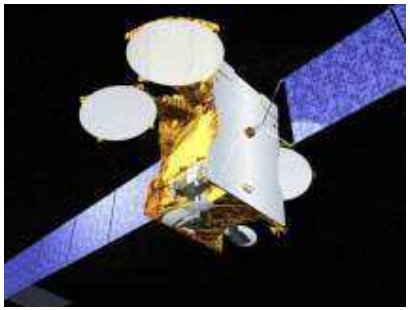
- Interest of wireless sensor network for space
- Description of the Astral network
- Performances of the ASTRAL wireless network

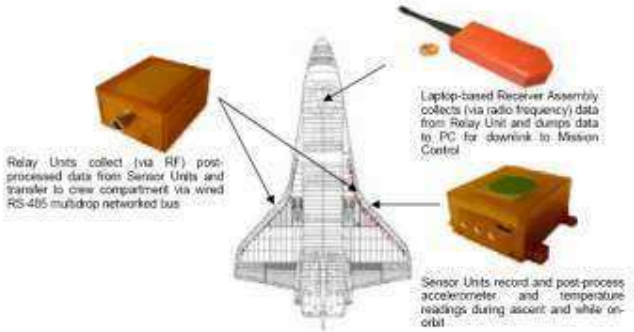
Interest of RF wireless

- **The field of application is multiple**
  - **The Assembly, Integration and Test (AIT) phase**:
    - satellite monitoring during the thermal and vibration system tests
  - **The satellite/launcher/shuttle *monitoring* during launch**:
    - shocks, sine 1 random vibration data
  - **The satellite/launcher/shuttle *monitoring* in flight**:
    - temperature, pressure, radiation data

Vibration test on VEX







Advantages / limitations of “RF wireless”

Attractiveness

- **Reduction of mass (**miniaturized sensors and less cabling)
- **Local and independent RF networks :** autonomous sensors
- **Add, remove and replace any sensor easily very late in the project**
- **Easy implementation ➔ saving time**
  - only one plug to the existing DHS system
  - Can be placed everywhere

Constraints

- **Limited by the life time of the power source supplying the wireless terminals**
- **RF emission power of the unit limited by the system EMC requirement**

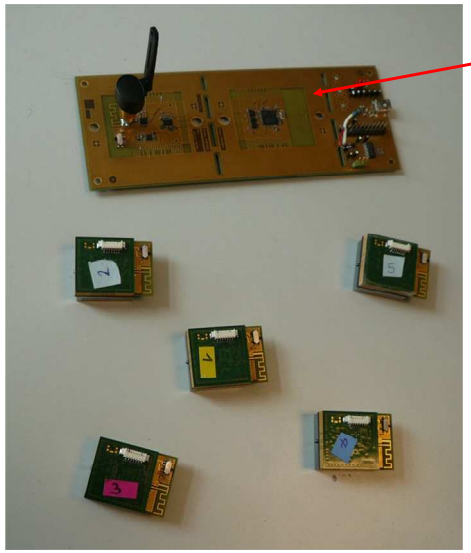
RF network dedicated to vibration monitoring (AIT phase)

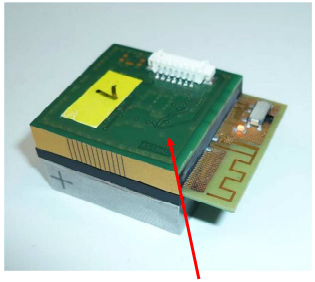
- One Master and 5 slave nodes
- A star network topology
  - The master : communication between the satellite and the nodes
    → manages the slaves and receives the measurements
  - Each slave node : a **miniaturized** self-powered sensor
    - *an **accelerometer 3D**, vibrations **20g***
    - *A specific **rechargeable battery** with high energy density*
    - *Compact : **40 x 30 x 20 mm***
    - *Light : **29g***

Architecture :

- *An electronic part (accelerometer, antenna, microcontroller…)*
- *The rechargeable battery*

the 2 compartments being strongly linked together



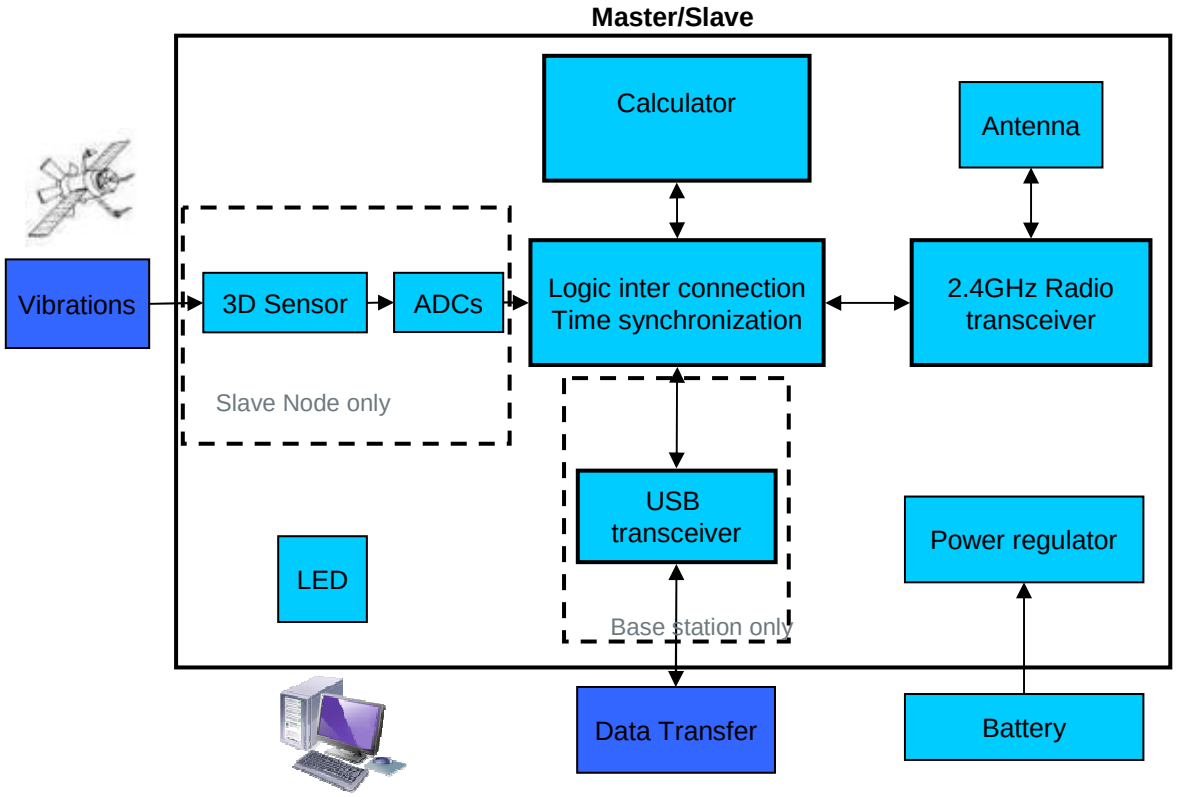


Master node

Slave node

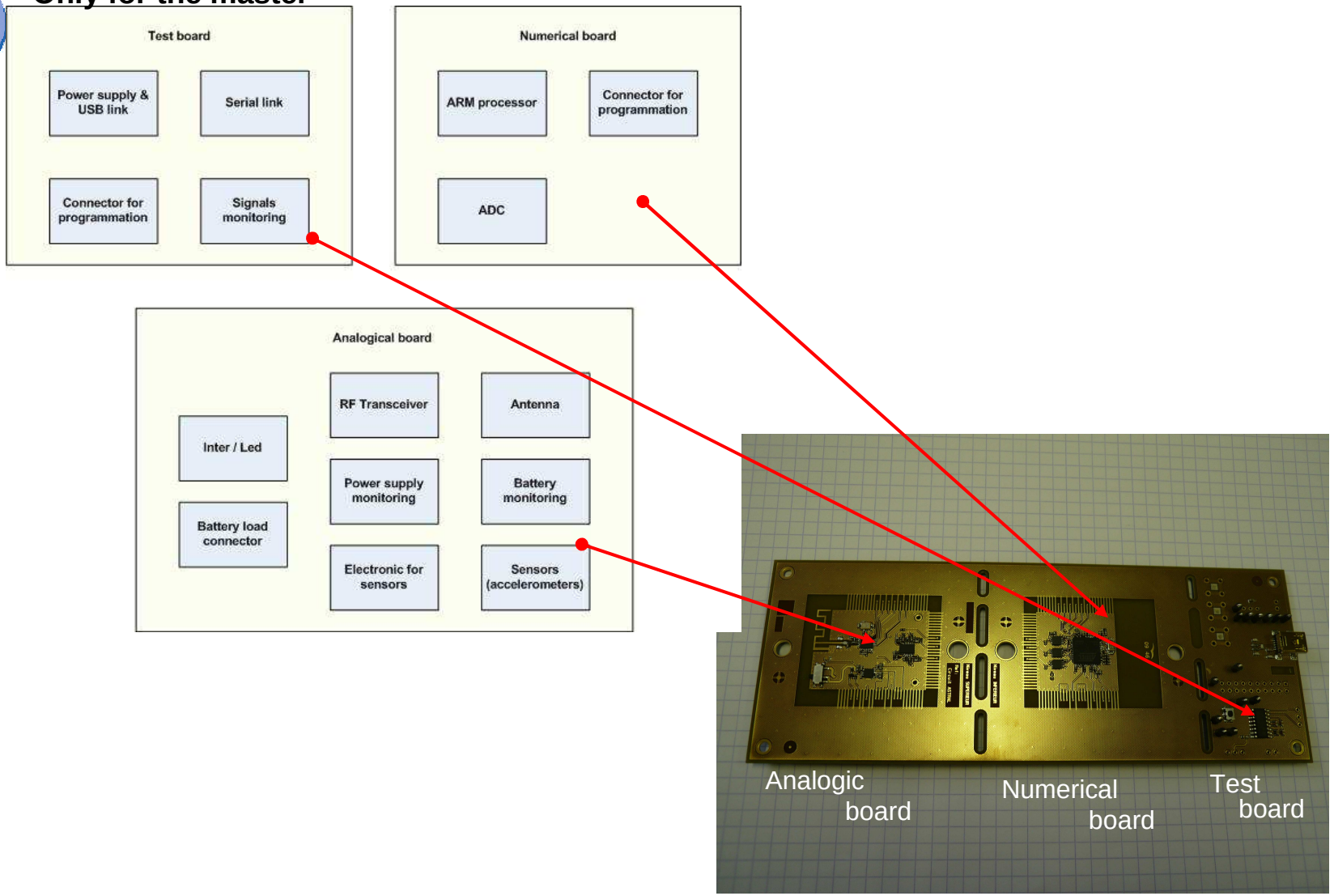
Node electronic architecture

- **A flexible architecture designed for allowing:**
  - **Master/Slave reversibility (same basic architecture, nature defined by simple programming)**
  - **Low optimized consumption**



Node electronic architecture

Only for the master

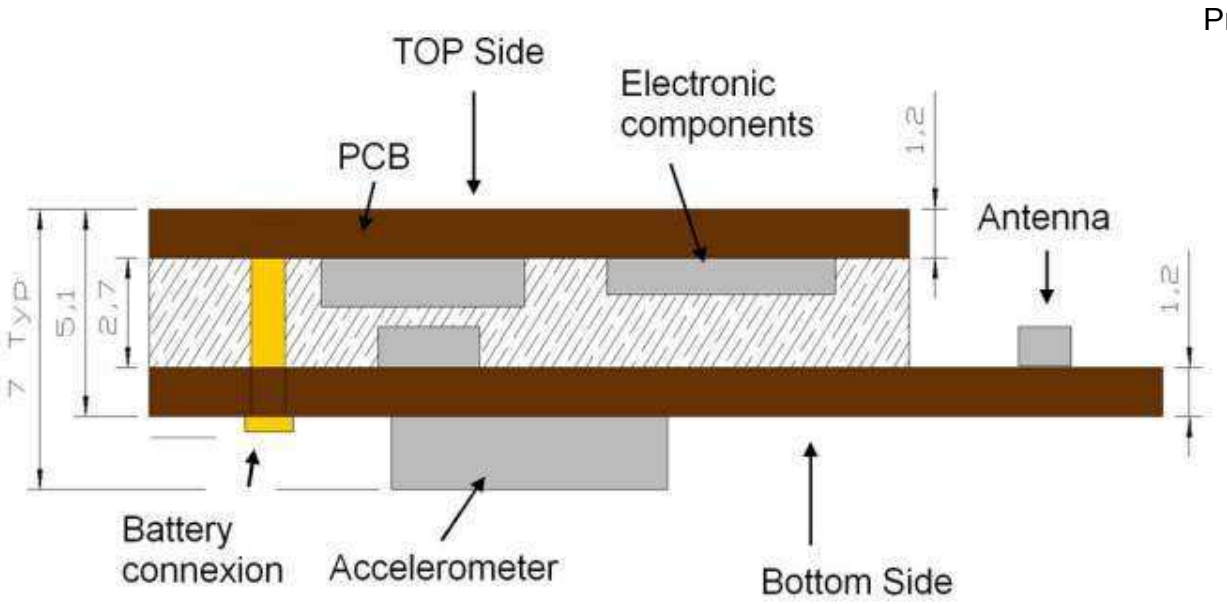


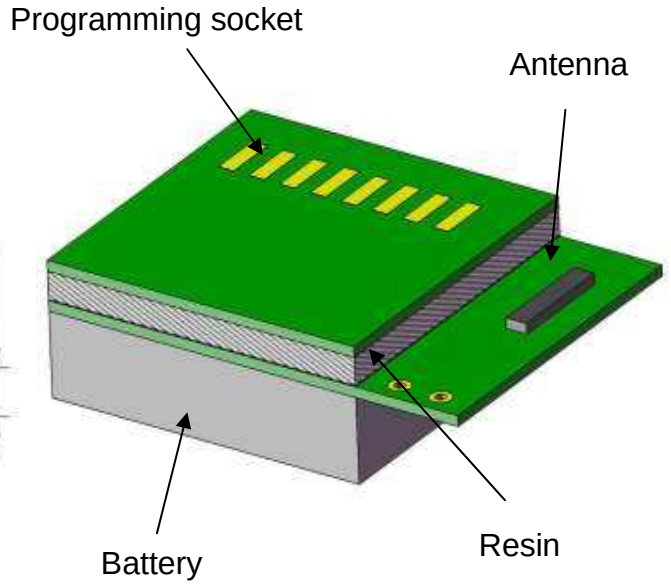
Hardware integration

A Space optimization

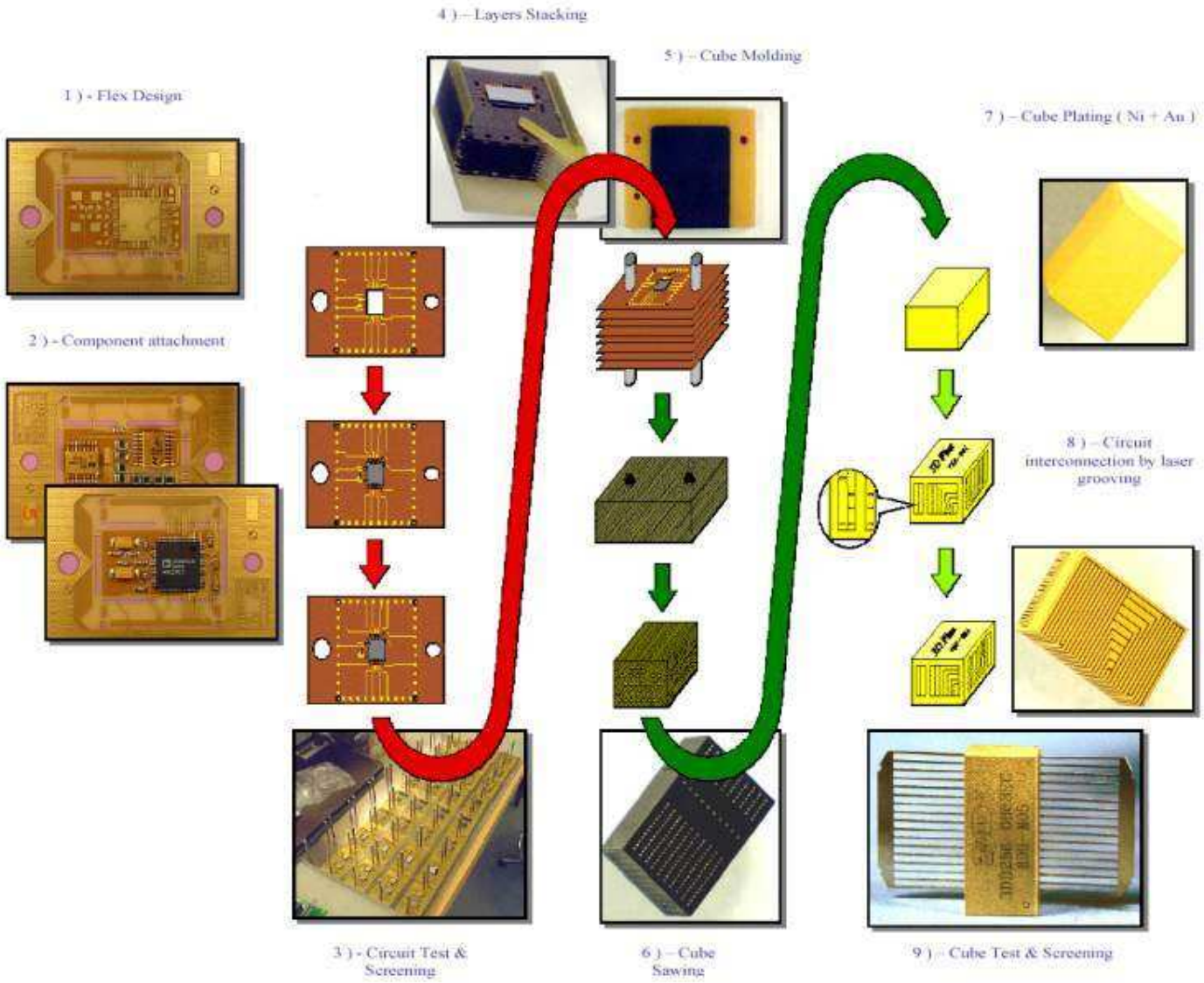
– **Compliant with some spatial constrains**

– **Tri axial design in a small factor form based on 3DPlus Space qualified technology**



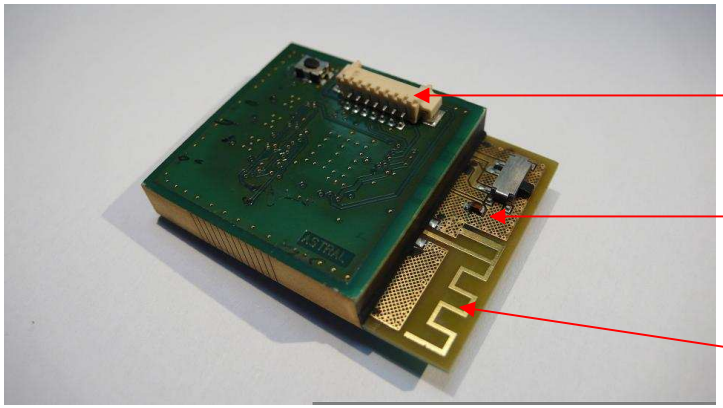


Process flow of the 3D Plus technology



Slave node in 3D Plus technology

Top view (« satellite side »)

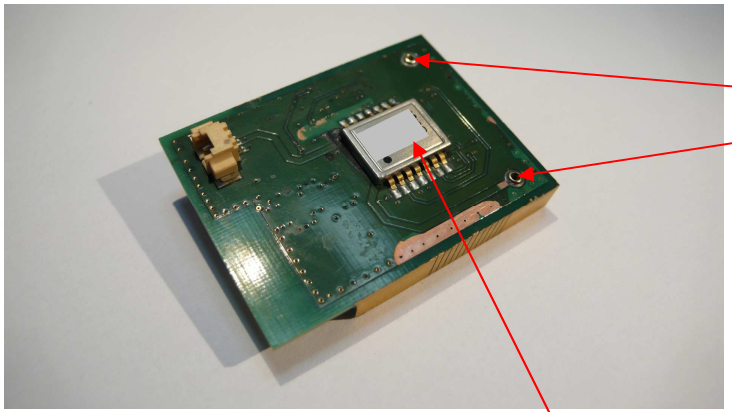


Programming sockets

Led showing the module when under tension

Antenna

Bottom view (« battery side »)



Cage jacks for the battery connection

3D Accelerometer sensor

A specific battery for each slave node

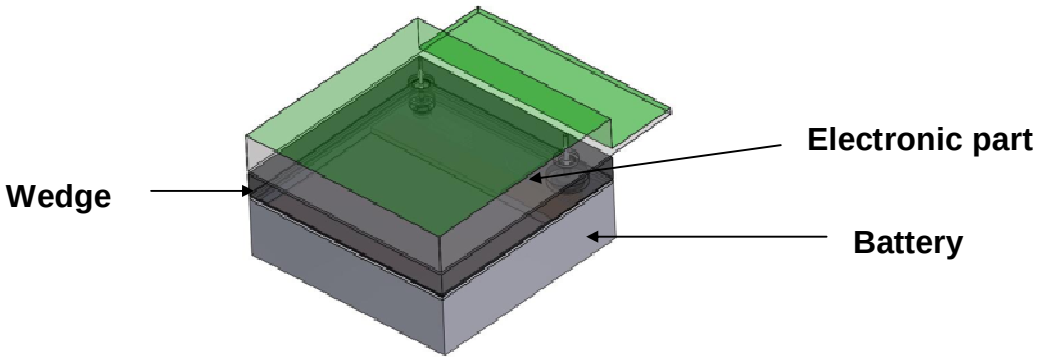
– High energy density and rechargeable (AIT tests)
→ Li-ion technology, 3.6 V

– Lifetime (at least 5 years)

– Temperature range (*tests on ground and storage : -40°C / +60°C)*
→ Specific technology

– Working in vacuum (*P = -10^{-10} torr)*
→ rigid and highly hermetic packaging, laser welded, GtMS

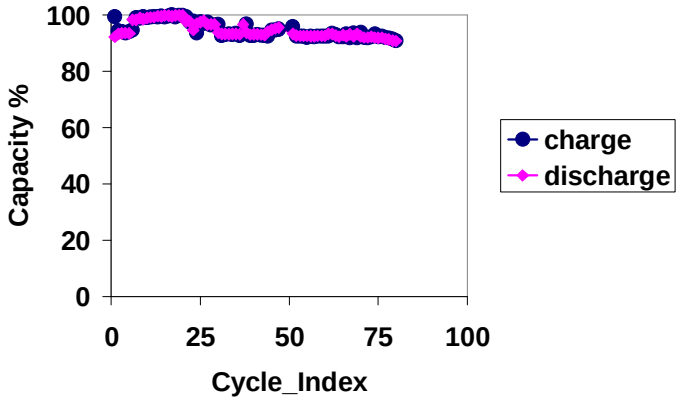
– Specific design *(compactness and resistant to vibrations)*
→ parallelepiped (overall 30 x 30 x 8.4mm), connections thanks to straight pins and use of wedge



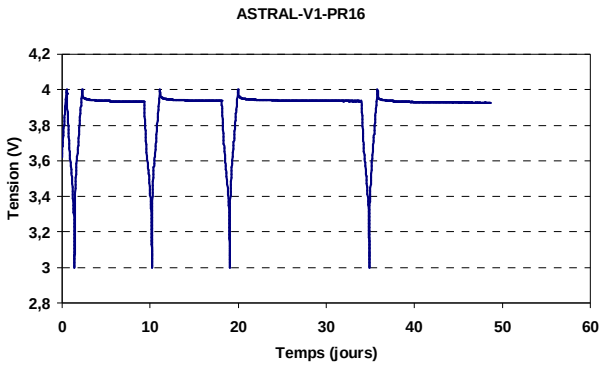
Electrical performances of the ASTRAL battery

Hermeticity of the casing : < 10^{-8} mbar.L.s^{-1}

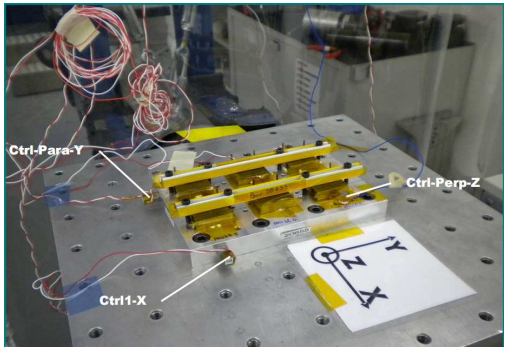
Technology	**NCA / Graphite** (CEA electrodes)
Nominal Capacity (mAh)	450
Nominal voltage (V)	3.6
Nominal Energy (Wh)	1.62
Cut-off Voltages (V)	3.0 - 4.0
Internal Resistance (mΩ)	175
Overall dimensions without pins (mm)	30 x 30 x 8.4
Volume (cm^3)	7.6
Mass (g)	15.5
Volumetric Energy Density (Wh/L)	213
Gravimetric Energy Density (Wh/kg)	105



Good cyclability : up than 80 cycles with the Astral using conditions



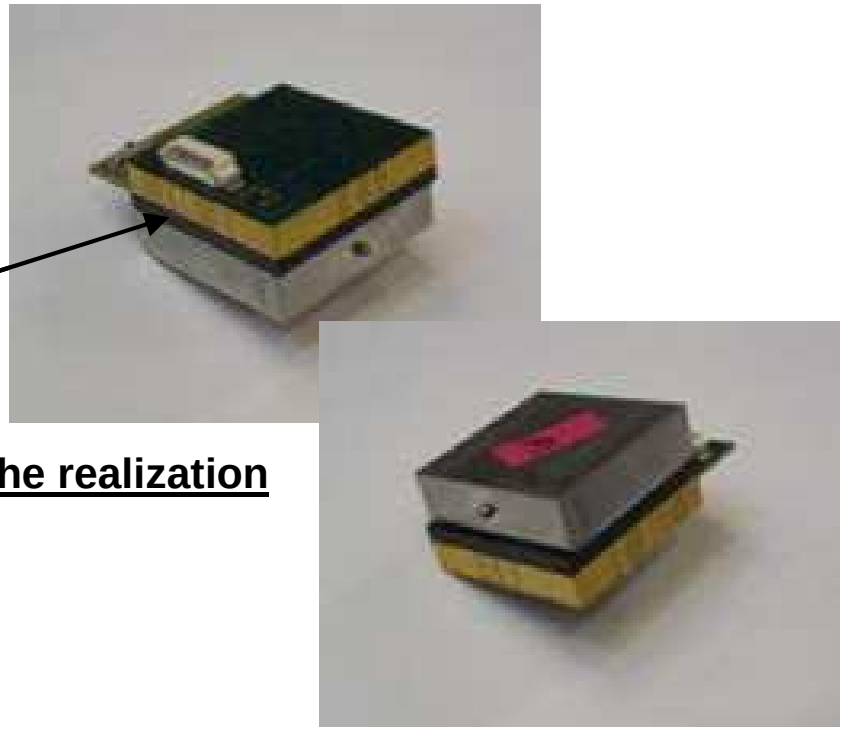
Self-discharge equivalent to the conventional Li-ion technology : about -1%/month



Qualified to the vibration tests: according to the space protocol

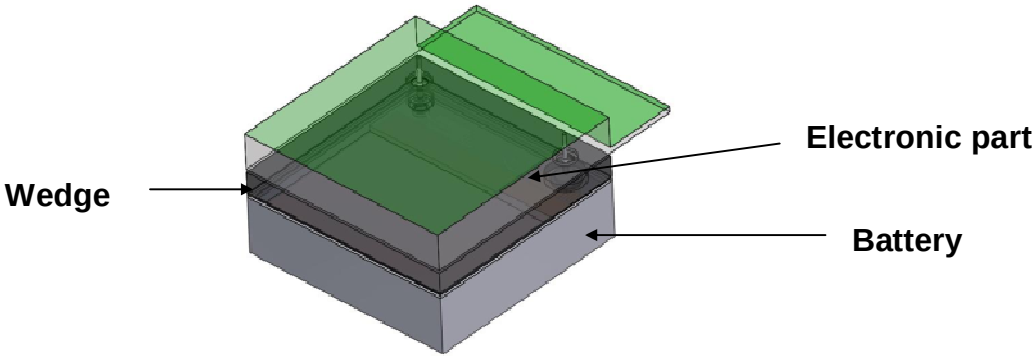
Assembly of a slave node

Wedge



The realization

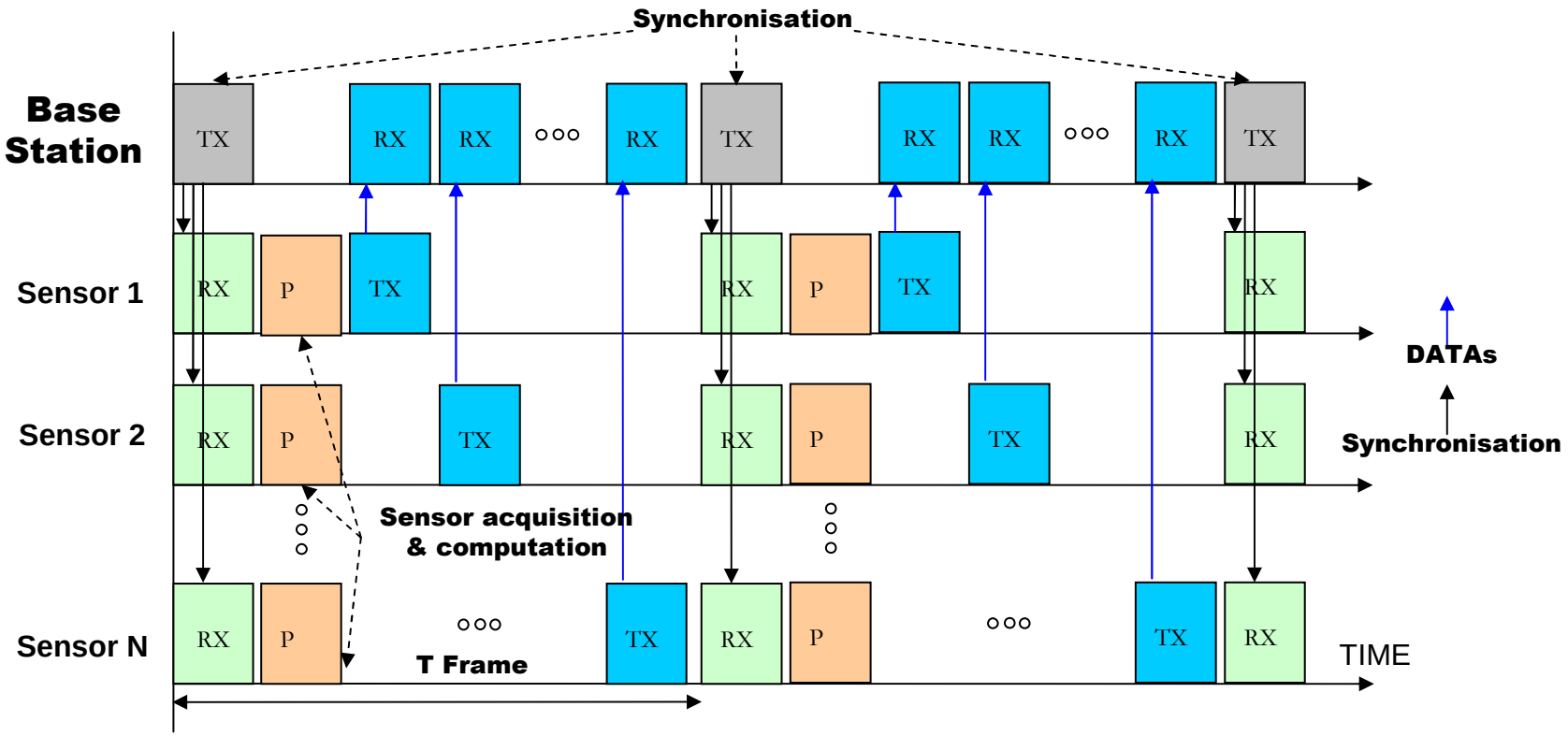
The objective



TDMA Protocol

Real Time flow

- A proprietary TDMA based protocol with ultra low latency
- Star Network topology



In this configuration, the bandwidth is limited by the master node reception. If we consider a bandwidth of 0.5Mbps, with 5 slave nodes in the network, and three times 16bits per slave node (tri axis accelerometer), the acquisition frequency is limited to 2 KHz.

Evaluation of the Astral network

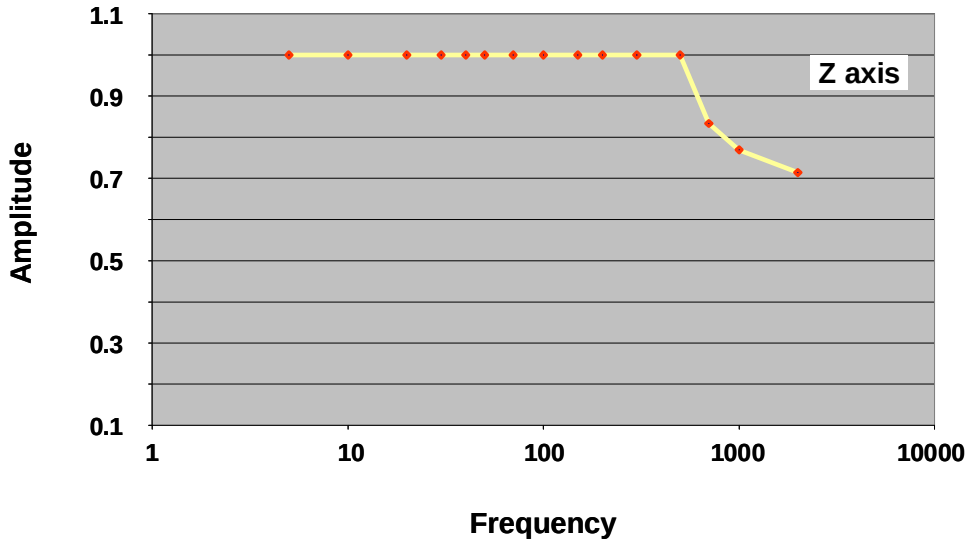
Vibration tests (use of commercial reference sensor):

Characteristics of the shaker :

Strength : 100N
Max. acceleration : 60g
Max. amplitude : 10mm
Mass of the sensor << 170g

Test conditions :

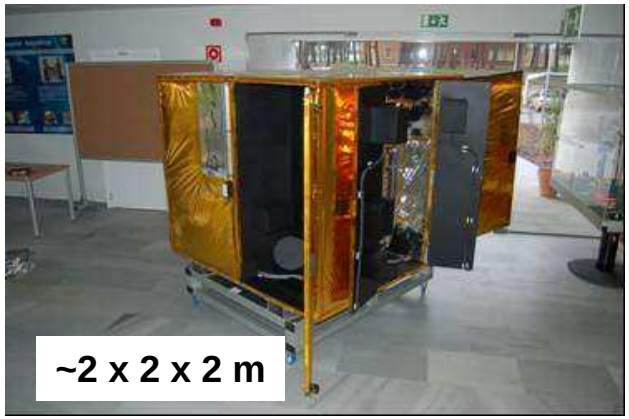
Working range of the sensor : ± 20g
The 3 axes X, Y and Z tested

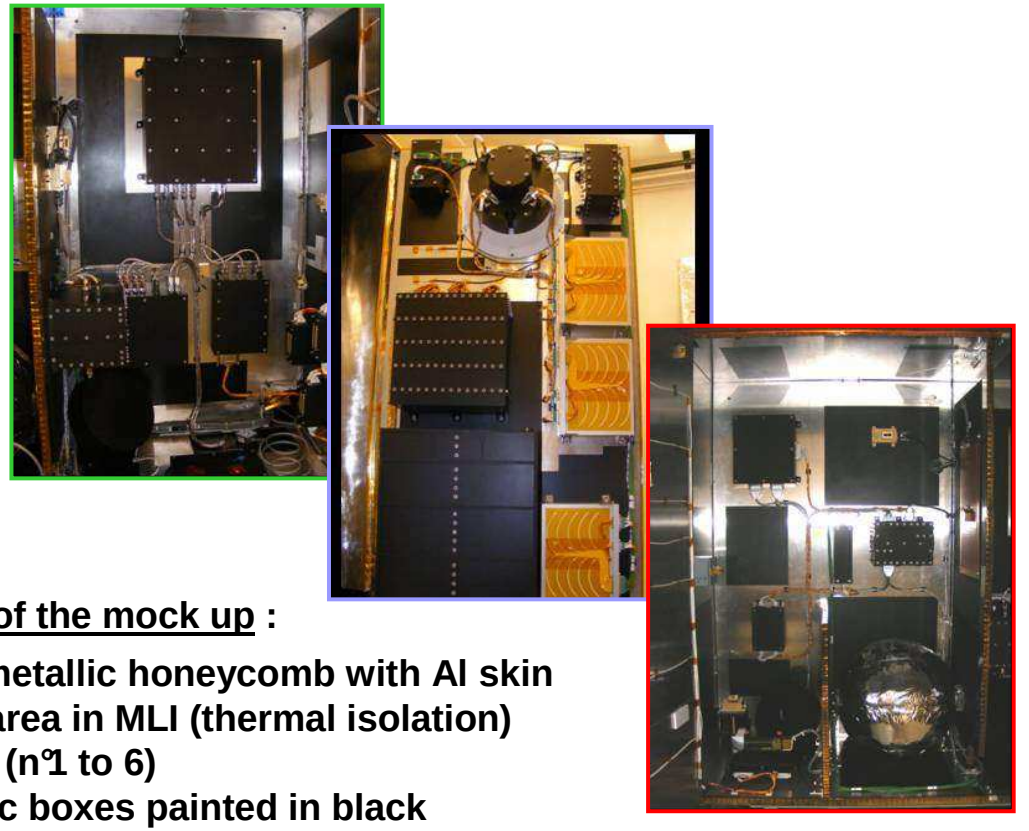


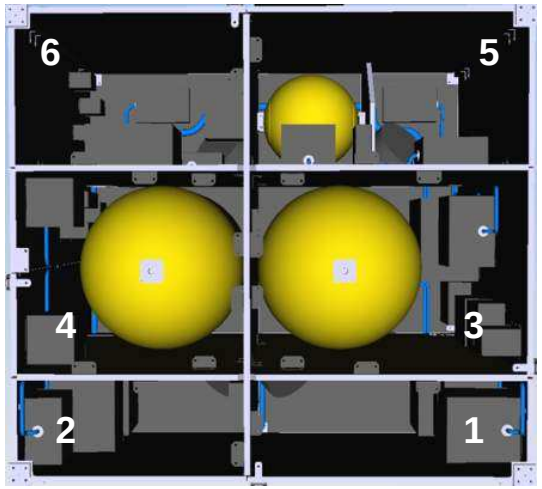
⇨ **Linear response up to 700Hz and cut at - 3dB at 2kHz**

Evaluation of the Astral network

Communication tests inside a mock up of satellite :





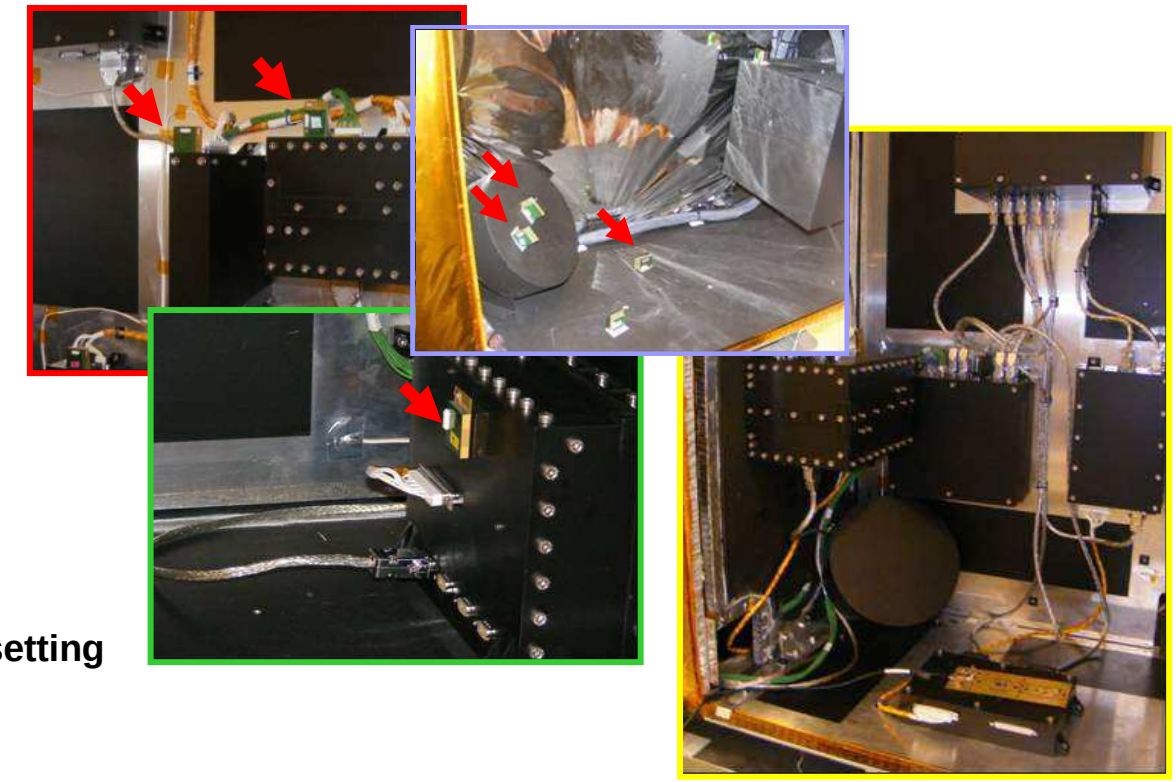


Description of the mock up :

- **Walls in metallic honeycomb with Al skin**
- **External area in MLI (thermal isolation)**
- **6 cavities (n°1 to 6)**
- **35 metallic boxes painted in black**
- **3 tanks**
- **Cabling**

Evaluation of the Astral network

Communication tests inside a mock up of satellite :



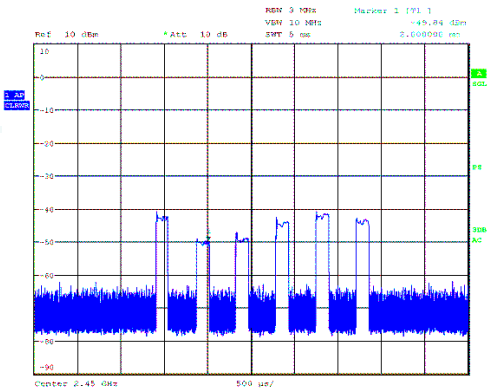
Slave nodes :
different configuration of setting

Tests conditions :

Radio frequency : 2.45 Ghz
5 slave nodes (SN) set up in 5 different cavities, then random distribution, fixed by adhesive
Position of the SN easily changed
Master node inside the mock up and connected to a PC by USB link

- ⇨ **Measurement of the BER**
- ⇨ **Evaluation of the consumption in active and stand by mode**
- ⇨ **RF range budget link**
- ⇨ **Determination of the limit threshold of communication**

Performances of the Astral network



- **No constraints of location for the nodes**
  → communication ensured whatever the location
- **BER ~ 0.4 and 4. 10^{-5}**
- **15mA in active mode, 700µA in sleeping mode**

Sensor	Tri axial accelerometer	± 20g, BW linear up to 700 Hz, cut at -3dB at 2kHz
A/D transceiver	16 bits	
Radio frequency	2.45 GHz	
Protocol	TDMA (home-made)	Real time with a mimimal latency of 5ms
Sampling frequency	Adjustable by software, from 1Hz to 2kHz	Network integrating 1 to 5 nodes ((Bandwidth of 0.5Mips to be shared between the slave nodes)
Processor	ARM 32 bits	Up to 60 Mbips (treatment may be embedded for increasing the BW)
Distance range	Equivalent to a volume of $40m^3$	The BER is about $10^{-5}/10^{-6}$ in a satellite
Number of SN possible	5	>5 inducing the reduction of the BW
SN dimensions	40*30*20mm	
SN weight	30g	
Power source of a SN	Specific Li-ion battery	450mAh, 3.6V, 150 to 250mΩ
Power of the NM	Through the USB connection	
Consumption of the SN	15 mA (at 1kS/s) => 30 hours	0.7 mA in stand-by mode => 30 days

Conclusion

- A network integrating :
  - The master connected to a PC
  - The slaves nodes in compact form constituted of:
    - Moulded electronic part
    - The battery

- A demonstrator to be declined
  - For various applications
  - Large potentiality in terms of specifications
    - the performances are not optimised (transmission parameters modifiable by software)
    - Sensor may be change
    - The power source may be adapted too (format, cyclability…)

ASTRAL

Partners involved in the development :

EADS-ASTRIUM, 3DPlus, CEA-DRT (Liten and Leti)

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Thank you for your attention

Contacts: helene.rouault@cea.fr **(power part)**
philippe.klein@cea.fr **(electronic part)**